[0195] This value V is compared with the ideal value U which is equal to the percentage of orangeness calculated assuming the angle of the provisional line is the same as that of the ideal line. For example, a pixel which is crossed by the line in the exact middle would have a U of 0.5, since it is 50% aqua and 50% orange. A fit of U-V in the column (or row) in the vicinity of the crossing of the provisional line gives a new estimate of the location of the true edge crossing. Finally, the set of these crossing points can be fit with a line or gentle curve for each of the three edges and the 3 vertices can be computed from the intersections of these lines or curves.

[0196] We can now use these three accurate vertices in the camera plane (F0,G0,F1,G1,F2,G2) together with lens formula (here we will use the simple lens formula for brevity) to relate the x and y of the target to F and G

$$F=\lambda X/Z;\ G=\lambda Y/Z$$

[0197] λ is the focal length and z is the perpendicular distance from the lens to a location on the target. A triangle on the target is initially defined as lying in a plane parallel to the lens plane. The preferred configuration has one right triangle whose right angle is defined at x0, y0, z0 with one edge (of length A) extending along the direction of the F axis of the camera and with the other edge (of length B) extending along the direction of the G axis of the camera. The actual target orientation is related to this orientation with the use of Euler Angles φ, θ, ψ. Together with the lens equations and the Euler equations, the 6 derived data values of the 3 vertices (F0, G0, F1, G1, F2, G2) can be used to define 6 values of location and orientaion of the target. The location and orientation of a point of interest on any tool or object rigidly attached to this target can be easily computed from calibration data and ordinary translation and rotation transformations. Refinements to handle lens distortions can be handled by forming a correction function with calibration data that modifies the locations of the F and G data.

[0198] The Euler formulation is nonlinear. We linearize the equations by assuming initially that the angles have not changed much since the last video frame. Thus we replace φ with φ(old)+U1θ with θ(old)+U2, ψ with ψ(old)+U3, and z0 with z0(old)+U4 or:

$$\phi=\phi+U1$$

$$\theta=\theta+U2$$

$$\psi=\psi+U3$$

$$z0=z0+U4$$

[0199] Substituting these into the Euler equations and applying the lens formulas leads to a matrix equation

$$S\ U=R$$

[0200] that can be solved for the U values with a standard methods such as Gauss Jordan routine. The angles and z0 can be updated iteratively until convergence is achieved. The coefficients of the matrix are defined as:

$$s11=-A(\cos(\phi)(F1/\lambda\ \cos\ (\psi)+\sin(\psi))-\sin\ (\phi)\cos(\theta)(F1/\lambda\ \sin\ (\psi)-\cos\ (\psi)))$$

$$s12=A\ \sin(\theta)\cos(\phi)(F1/\lambda\ \sin(\psi)-\cos(\psi)$$

$$s13=A(\sin(\phi)(F1/\lambda\ \sin(\psi)-\cos(\psi))-\cos(\phi)\cos(\theta)(F1/\lambda\ \cos(\psi)-\sin(\psi)))$$

$$s14=(F0-F1)/\lambda$$

$$s21=A(G1/\lambda(-\cos(\phi)*\cos(\psi)+\sin(\phi)\sin(\psi)\cos(\theta))+\sin(\theta)\sin(\phi))$$

$$s22=A\ \cos(\phi)(G1/\lambda\ \sin(\theta)\sin\ (\psi)-\cos(\theta))$$

$$s23=G1/\lambda A(\sin(\psi)\sin(\phi)-\cos(\psi)\cos(\theta)\cos(\phi))$$

$$s24=(G0-G1)/\lambda$$

$$s31=0$$

$$s32=-B\ \cos(\theta)(F2/\lambda\ \sin(\psi)-\cos(\psi))$$

$$s33=-B\ \sin(\theta)(F2/\lambda\ \cos(\psi)+\sin(\psi))$$

$$s34=(F0-F2)/\lambda$$

$$s41=0$$

$$s42=-B(G2/\lambda\ \sin(\psi)\cos(\theta)+\sin(\theta))$$

$$s43=-B\ G2/\lambda\ \sin(\theta)\cos(\psi)$$

$$s44=(G0-G2)/\lambda$$

[0201] and the right hand side vector is defined as:

$$r1=(F1-F0)z0/\lambda+A(F1/\lambda(\cos(\psi)\sin(\phi)+\cos(\theta)\cos(\phi)\sin(\psi))\sin\psi)\sin(\phi)-\cos(\theta)\cos(\phi)\cos(\psi))$$

$$r2=(G1-G0)z0/\lambda+A(G1/\lambda(\cos(\psi)\sin(\phi)+\cos(\theta)\cos(\phi)\sin(\mathbf{104}\ ))+\sin(\theta)\cos(\phi))$$

$$r3=(F2-F0)z0/\lambda+B\ \sin(\theta)(F2/\lambda\ \sin(\psi)-\cos(\psi))$$

$$r4=(G2-G0)z0/\lambda+B(G2/\lambda\ \sin(\theta)\sin(\psi)-\cos(\theta))$$

[0202] After convergence the remaining parameters x0 and y0 are defined from the equations:

$$x0=F0\ z0/\lambda$$

$$Y0=G0\ z0/\lambda$$

[0203] The transition of pronounced colors can yield considerably more information than a black white transition, and is useful for the purpose of accurately calculating position and orientation of an object. As color cameras and high capacity processors become inexpensive, the added information provided can be accessed at virtually no added cost. And very importantly, in many cases color transitions are more pleasing to look at for the user than stark black and white. In addition the color can be varied within the target to create additional opportunities for statistically enhancing the resolution with which the target can be found.

[0204] Problems in 3Dimensional Input to Computers

[0205] Today, input to a computer for Three Dimensional (3D) information is often painstakingly done with a 2 Dimensional device such as a mouse or similar device. This artifice, both for the human, and for the program and its interaction with the human is un-natural, and CAD designers working with 3D design systems require many years of experience to master the skills needed for efficient design using same.

[0206] A similar situation exists with the very popular computer video games, which are becoming ever more 3 Dimensional in content and graphic imagery, but with similar limitations. These games too heretofore have not been natural for the player(s).

[0207] "Virtual reality" too requires 3D inputs for head tracking, movement of body parts and the like. This has lead to the development of a further area of sensor capability which has resulted in some solutions which are either cumbersome for the user, expensive, or both.

[0208] The limits of computer input in 3D have also restricted the use of natural type situations for teaching, simulation in medicine, and the like. It further limits young children, older citizens, and disabled persons from benefiting from computer aided living and work.